AD-A085 343 ROYAL AIRCRAFT ESTABLISHMENT FARNBOROUGH (ENGLAND) F/G 20/4
WIND-TUNNEL/FLIGHT COMPARISON OF THE LEVELS OF BUFFETING RESPON--ETC(U)
MAY 79 G F BUTLER, G R SPAVINS
UNCLASSIFIED RAE-TM-AERO-1806 DRIC-BR-69201 NL

1 OF 1
AD
A085343

END
DATE
FILMED
7-80
DTIC

TECH. MEMO
AERO 1806

TECH. MEMO
AERO 1806

ROYAL AIRCRAFT ESTABLISHMENT

WIND-TUNNEL/FLIGHT COMPARISON OF THE LEVELS OF BUFFETING RESPONSE INTENSITY FOR THE TACT F-111

by

G. F. Butler
G. R. Spavins

May 1979

ROYAL AIRCRAFT ESTABLISHMENT

Technical Memorandum Aero 1806

(11) Received for printing 31 May 1979

(6)

WIND-TUNNEL/FLIGHT COMPARISON OF THE LEVELS OF BUFFETING RESPONSE INTENSITY FOR THE TACT F-111

by

(10) G. F. Butler
G. R. Spavins

(12) 21

(9) Technical memo.

(18) DRIC

(19) BR-69201

SUMMARY

Under a UK/US collaboration programme, a wind-tunnel/flight correlation has been made of the levels of buffeting response intensity of the TACT F-111 aircraft. Using a technique which has been under development at RAE, wind-tunnel measurements of the buffeting response of a 1/8-scale half-model of conventional construction have been used to predict the response of the TACT aircraft under full-scale flight conditions. Comparison with flight measurements shows good agreement.

(14) RAE-TM-AERO-1806

Paper presented at USAF/NASA Symposium on Transonic Aircraft Technology, Lancaster, California, August 1978

310450

LIST OF CONTENTS

1 INTRODUCTION

Under a UK/US collaboration programme, a wind-tunnel/flight correlation has been made of levels of buffeting response intensity for the TACT F-111 aircraft. The correlation extends the validity of a technique for predicting buffeting response in flight from wind-tunnel measurements which has been under development at RAE[1-3]. The technique involves the measurement of unsteady accelerations or bending moments on a wing of solid construction, of the type normally produced for conventional 'force' tests. An outline of the approach is given below and illustrated in Fig 1. If each mode of the model is assumed to behave as a single-degree-of-freedom mechanical system, the response of the model under buffeting conditions can be analysed to give a measure of the aerodynamic excitation and total damping ratio. The latter comprises both structural and aerodynamic components and, since the structural damping of the model can be measured in a wind-off resonance test, the aerodynamic damping can be extracted. The buffeting response of the aircraft can then be predicted, using values of aerodynamic excitation and aerodynamic damping scaled from model tests, together with estimated or measured values of aircraft structural damping. It is generally found that a conventional wind-tunnel model has modes of vibration which, for the lower and more important modes, are similar to those of the aircraft and, in principle, the technique can be applied to all aircraft modes which can be reproduced approximately, in terms of frequency and mode-shape, on the model.

An important requirement is that the structural damping of the model should be low, thus allowing the aerodynamic damping to be estimated from the measurements of total damping with reasonable accuracy. In general, for wind-tunnel tests of conventional steel models, the structural damping is predominant, in contrast to the corresponding flight condition, where the major damping component is usually of aerodynamic origin[4]. However, recent measurements of buffeting on wind-tunnel models[2,3,5] have shown that significant levels of aerodynamic damping can be measured under tunnel conditions provided the model and mounting are constructed with as few joints as possible, in order to minimise the structural damping. In addition, since the level of aerodynamic damping is inversely proportional to the density of the model, a model made of light alloy will give a greater aerodynamic damping component than one made of steel.

Initial evaluation of the prediction method was carried out in the UK, for a small combat trainer aircraft, and very good agreement was obtained between the predicted response and that measured in flight[2,3]. Following this a UK/US collaborative programme was agreed for wind-tunnel and flight measurements of the

buffeting response of the TACT F-111 aircraft. These tests would allow further validation of the technique and complement the US work based on measurements of the unsteady pressures on the wing under buffeting conditions. Accordingly a 1/8-scale half-model of the TACT F-111 was provided by the US and tested by the UK in the 8ft × 8ft wind-tunnel at RAE Bedford. In addition, recordings of the buffeting response of the aircraft in flight were made available by the US. The analysis of both tunnel and flight data and the flight-tunnel comparison are being carried out in the UK.

In this paper, the initial results of this correlation are presented. Analysis of the data for the first wing bending mode is nearing completion and the results given here are limited to this mode. Analysis of the torsion modes is proceeding and results will be available shortly. The prediction technique and the analysis methods used are described in section 2, while, in section 3, details of the wind-tunnel tests are given and, in section 4, the flight/tunnel correlation is presented.

2 THE BUFFETING PREDICTION METHOD AND ANALYSIS TECHNIQUES

In this section, the method of buffeting prediction is described in more detail. The aim of the analysis is to find a non-dimensional representation of the important aerodynamic parameters, so that measurements of these parameters in the wind-tunnel can be used to predict buffeting response in flight. We assume a linear forced-vibration model and neglect aerodynamic stiffness and inertia forces together with aerodynamic coupling between modes. The response of the wing in any flexible mode to the unsteady excitation associated with flow separations may be expressed as a function of time t in terms of a generalised coordinate $z(t)$, representing displacement in that mode and a generalised aerodynamic excitation $X(t)$, assumed to have no feedback from the wing motion. The response in the mode is then defined by

$$m \frac{d^2z}{dt^2} + 2m\zeta\omega_0 \frac{dz}{dt} + m\omega_0^2 z = X(t) \qquad (1)$$

where m is a generalised mass, ω_0 is the undamped natural frequency and the term $m\omega_0^2$ represents the structural stiffness. The total damping ratio ζ is given by

$$\zeta = \zeta_a + \zeta_s , \qquad (2)$$

where ζ_a and ζ_s are the aerodynamic and structural components respectively.

Firstly we consider the aerodynamic excitation term on the right hand side of equation (1). By expressing the displacement $Z(t)$ in the form of a Fourier integral, a relationship can be derived between the power spectral density of the response $G_z(f)$ and the power spectral density of the excitation $G_x(f)$. If we assume that the excitation spectrum does not vary appreciably in the neighbourhood of the mode natural frequency, $f_0 = \omega_0/2\pi$, then it can be shown that the rms acceleration response $\sigma_{\ddot{z}}$ is given by

$$\sigma_{\ddot{z}} = \frac{\sqrt{\pi}}{2}\left[\frac{f_0 G_x(f_0)}{\zeta m^2}\right]^{\frac{1}{2}} . \tag{3}$$

We now assume that the appropriate length and velocity parameters for scaling frequency are the mean wing chord $\bar{c}$ and flow velocity V, and that the mean square fluctuating force scales with $(qS)^2$, where q is the dynamic pressure and S is the wing area. Hence $G_x(f)$ can be expressed in the form

$$G_x = \frac{E^2\bar{c}}{V}(qS)^2 , \tag{4}$$

where E is a non-dimensional aerodynamic parameter, a function of wing incidence, Mach number and Reynolds number. Equations (3) and (4) can be combined to give the aerodynamic excitation parameter E as

$$E = \left(\frac{2m}{S}\right)\left(\frac{2}{n_0}\right)^{\frac{1}{2}}\left(\frac{\zeta^{\frac{1}{2}}\sigma_{\ddot{z}}}{q}\right) , \tag{5}$$

where $n_0 = \bar{c}\omega_0/V$ is the non-dimensional modal frequency. One method for the evaluation of E involves the measurement of fluctuating pressures on relatively rigid wind-tunnel models and the derivation of the generalised force by means of cross-correlation techniques. Alternatively E may be derived from wind-tunnel tests on the basis of equation (5) using models for which the relevant mode shape is approximately correct. To obtain E from equation (5), wind-tunnel measurements of the rms acceleration and total damping ratio are required, together with a knowledge of the modal frequency and generalised mass. We will assume that the parameter E characterises the aerodynamic excitation in the mode concerned for a given Mach number and incidence, and can be used to determine the buffeting response of the full-scale aircraft from equations (3) and (4). Again a

knowledge of the aircraft modal frequency and generalised mass is required as well as the total damping ratio.

The total damping ratio under flight conditions can be estimated from the total damping ratio measured in wind-tunnel tests as follows. If the structural damping ratio ζ_s for the model is determined in a wind-off resonance test, the aerodynamic damping ratio ζ_a can be found from the measured total damping using equation (2). The aerodynamic damping force arises from the effective incidence of the wing due to its vibration and the corresponding term in equation (1) can be expressed in the form:

$$2m\zeta_a\omega_0\dot{z} = 2qSK\dot{z}/V \quad , \tag{6}$$

where K is a non-dimensional parameter which depends on the mode shape, the planform of the wing and the distribution of the frequency-dependent lift-curve slope over the wing. Hence from (6)

$$\zeta_a = \frac{qSK}{m\omega_0 V} \tag{7}$$

and

$$K = \frac{m\omega_0 V\zeta_a}{qS} \quad . \tag{8}$$

It is now assumed that the parameter K characterises the aerodynamic damping in the mode concerned for a given Mach number and incidence, and that once determined from model tests, K can be used to calculate the aerodynamic damping appropriate to flight conditions from equation (7). By combining this with the measured or estimated aircraft structural damping, an estimate of the total damping ratio in flight can be derived.

In order to apply the technique described above, the rms response σ and total damping ratio ζ in each mode of interest need to be extracted from the unsteady accelerometer or strain-gauge signals recorded in a wind-tunnel test. Methods for the estimation of ζ and σ from random signals are described in Refs 2 and 3, and the discussion is summarised below.

A random response signal typical of buffeting is shown in Fig 2. The curve itself is so variable that it is difficult to extract modal information (*ie* frequency, rms response and damping) directly and, in general, some technique for condensing the information into a more orderly format is used. The three

procedures which are applied most commonly are (i) power spectral density, (ii) autocorrelation and (iii) random decrement (randomdec)[6]. In Ref 2, it is concluded that the 'response' functions (*ie* randomdec or autocorrelation) are the most suitable for the analysis of buffeting signals. (The term response function is used, since both the autocorrelation and randomdec functions approximate to the step response of the system.)

For a single-degree-of-freedom system, the frequency, rms response and damping can be extracted directly from the exponentially decaying response function. For multi-degree-of-freedom systems, however, the response functions will no longer exhibit a uniform exponential decay owing to the mutual cancellation and reinforcement of the modal components. Often it is possible to eliminate unwanted modes by filtering, but when the modes lie too close together for effective filtering, a further analysis step will be needed to extract the modal parameters. The usual approaches to this problem involve either a curve-fit of the response function data to a sum of exponentially decaying sine waves[7] or a curve-fit of the Fourier transform of the response function to a sum of single-degree-of-freedom transfer functions[8,9]. The technique applied to the TACT buffeting data[9] is to fit a function of the form

$$H(\omega) = -\frac{1}{2}\sum_{k=1}^{m} \frac{r_k}{\omega + ip_k} - \frac{r_k^*}{\omega + ip_k^*} ,$$

where $*$ denotes the complex conjugate, to the Fourier transform of the response function. The poles p_k in the above equation are given by

$$p_k = -\frac{\omega_k \zeta_k}{\left(1 - \zeta_k^2\right)^{\frac{1}{2}}} + i\omega_k ,$$

where ω_k, ζ_k are the natural frequency and damping ratio in the kth mode respectively. The modal parameters are estimated using an iterative optimisation algorithm to minimise the mean square error between $H(\omega)$ and the transformed response function.

3 WIND-TUNNEL TESTS ON A 1/8-SCALE HALF-MODEL OF THE TACT AIRCRAFT

The model was designed and manufactured in the US under an AFFDL contract. Details of the design and mounting of models used in earlier buffeting tests[2,3]

were provided by the UK. The testing was carried out in the 8ft × 8ft wind-tunnel at RAE Bedford.

3.1 Experimental details

Details of the model mounted in the 8ft × 8ft wind-tunnel are shown in Fig 3. The wing was made out of a solid block of aluminium alloy and was attached to a steel root-block and thence to the half-model balance by an arrangement of pre-stressed bolts known to have low structural damping. A change of sweep from 26° to 35° was catered for by the provision of two sets of bolt holes and location dowels in the root-block. The fuselage was made from glass-reinforced plastic and, in order to minimise structural damping on the wing, was mounted independently on an earth-ring surrounding the balance. The centre line of the fuselage was offset approximately 1 inch (25 mm) from the tunnel sidewall to avoid interference from the sidewall boundary layer. The fin and tail were not represented and the intake was faired over. The gap of approximately 0.2 inch (5 mm) between the wing and fuselage was sealed with foam plastic strip covered with a thin layer of silicon rubber. Earlier tests had confirmed that this arrangement provided an effective seal and had a very small effect on the wing structural damping. The wing was instrumented with five accelerometers and a wing-root bending moment bridge as shown in Fig 3.

The test Mach number was 0.8 and the Reynolds number, R (based on mean chord) was varied over the range 5.4×10^{6} to 10.8×10^{6} giving a two-to-one change in dynamic pressure and hence in aerodynamic damping. At each angle of incidence, the forces from the half-model balance were recorded and a 30 second sample of the model response as measured by the accelerometers and strain gauges was recorded on magnetic tape.

Transition was fixed using a 0.1 inch (2.5 mm) wide band of sparsely distributed ballotini, positioned either at 5% chord or at 15% chord. The size of ballotini was originally selected according to the criteria in Ref 10 as 0.0055 inch (0.014 mm) for the forward band and 0.0075 inch (0.019 mm) for the rearward band. Early tests with the transition band at 5% chord indicated a difference in the behaviour of lift coefficient C_L with angle of incidence as Reynolds number was increased at angles just beyond buffet onset. An increase in the size of ballotini used for the forward band to 0.009 inch (0.023 mm) eliminated this effect, and this size was retained for subsequent tests. The major part of the tests were carried out with the wing at 26° sweep, where the model was tested transition-free, with two sizes of ballotini at 5% chord and with one size at 15% chord. At 35° sweep tests were performed transition-free and with the larger, forward transition-band only.

In order to determine the non-dimensional excitation and aerodynamic damping parameters E and K, it is necessary to know ω_0, the natural frequency, ζ_s, the structural damping, and m, the generalised mass of the mode. These structural parameters were measured for three modes of the model (first and second bending and first torsion) in a wind-off resonance test in which the model was excited with an electromagnetic shaker. The natural frequency and structural damping were determined from the amplitude and phase-change of the response as the excitation frequency was varied, and the generalised mass was measured directly from the change in natural frequency due to the addition of a small mass to the wing[11]. In addition, the mode shape was estimated by measuring the response at a grid of points on the wing. Fig 4 shows the mode shape for first bending compared with that measured on the TACT aircraft[12,13].

3.2 Results of buffeting response measurements

The recordings of the wing response were analysed digitally using a Hewlett-Package 5451A Fourier analysis computer system. Both the rms response σ and the damping ζ were determined from the autocorrelation function of the response using the modal analysis procedure, MADAM[9] referred to in section 2. In fact the modes of the model were sufficiently widely spaced for separation by filtering so that the damping estimates could be checked directly from the decay of the autocorrelation function.

Typical power spectra of the response of the wingtip accelerometer on the model and aircraft are shown in Fig 5. Results from the first wing bending mode only are presented here. It should be noted that the second wing bending mode on the model has no corresponding mode on the full-scale aircraft whereas, owing to mass asymmetry effects, the aircraft responds in several torsional modes[14].

Wind-tunnel measurements of the rms wingtip acceleration σ and total damping ratio ζ in the first wing bending mode *vs* angle of incidence α are shown in Figs 6 and 7 for 26^o and 35^o sweep respectively, with transition fixed at 5% chord. It can be seen that, in general, for a given angle of incidence both the response and damping increase with Reynolds number and hence with dynamic pressure. This is to be expected if the aerodynamic damping is predominant, in which case $\sigma \sim \rho$, where ρ is the air density[4]. Although there are variations of damping with incidence, and considerable scatter, particularly at 35^o sweep, in overall terms the damping data are consistent with the constant value of structural damping (0.2% critical) measured in the model resonance test, (*cf* Ref 2, where both the resonance test and the damping measurements were used to infer that the structural damping varied with the level of response). The

values of E and K corresponding to the data of Figs 6 and 7 have been calculated from equations (5) and (8) and the parameters given in Tables 1 and 2. These are shown in Figs 8 and 9, where the lines joining the data points are intended to indicate the scatter band. It should be noted that E is plotted on a logarithmic scale to show that the reduction of the measurements to non-dimensional form has collapsed the rms response data with some success. The data for K against α are fairly scattered, but show a significant variation of aerodynamic damping with incidence at 26^o sweep. In contrast, no significant variation of damping with Reynolds number (or dynamic pressure) is indicated.

4 FLIGHT/TUNNEL COMPARISON OF BUFFETING RESPONSE

The curves for the variation of E and K with α (Figs 8 and 9), have been used to predict the buffeting response in the first wing symmetric bending mode for full-scale flight conditions. To reduce the scatter in the data, weighted means of the values plotted were used in the prediction calculations. Weighting factors of 2, 1.5 and 1 were applied for $R = 10.8$, 8.1 and 5.4×10^6 respectively, thus weighting the values to the higher Reynolds numbers, where scale effects on the buffeting response would be expected to be smaller and the aerodynamic damping component would be expected to be larger. Values of the aircraft structural parameters were taken from the results of the aircraft ground vibration test[12,13], where data for sweeps of 26^o and 45^o are given. The values used for the structural parameters at 35^o sweep were estimated by linear interpolation. The generalised mass relative to the aircraft tip accelerometer position was calculated from the mode shape and mass distribution data. It should be noted that this operation involves some uncertainty, since the aircraft accelerometer lies midway between two of the measurement points in a region where the mode shape is changing rapidly. The mode shapes for the model and aircraft at 26^o sweep are compared in Fig 4.

Using equations (2), (3), (4) and (7) with the values given in Tables 1 and 2, the total damping and the rms response at the aircraft accelerometer were predicted and are plotted in Figs 10 and 11 for 26^o and 35^o sweep respectively. The solid lines represent estimates based on the tunnel data with transition fixed at 5% chord and the dashed lines of Fig 10 are based on tunnel data with transition fixed at 15% chord. (The 35^o sweep configuration was not tested with aft transition.) In both cases, estimates for flight Reynolds numbers of 24×10^6 and 32×10^6 have been calculated. Also shown in Figs 10 and 11 are values of rms response and damping obtained from flight measurements of the right wingtip accelerometer signal from the TACT aircraft. The flights were made over

two altitude ranges 27000 to 31000 feet (8250 to 9450 metres) and 17000 to 21000 feet (5200 to 6400 metres) corresponding to flight Reynolds numbers of approximately 31 to 35 × 10^6 and 22 to 26 × 10^6 respectively. The target condition was to hold Mach number and angle of incidence constant for 100 seconds (*ie* approximately 500 cycles of the first symmetric wing bending mode). Altitude was to be held as steady as possible within the altitude range concerned. As the aircraft penetrated into buffet it was increasingly difficult to hold conditions constant for the prescribed time period and so data was obtained over several shorter runs.

The data have been analysed with the same autocorrelation and modal analysis procedures as used with the wind-tunnel data described in section 3. It is intended to average the autocorrelation signatures over a number of runs, so that at least 500 cycles of the first wing bending mode are covered. However, the selection basis of data for this averaging has yet to be finalised and hence the rms response and damping for the individual runs are plotted, representing samples of duration between 150 and 600 cycles of the mode. It is expected that the averaged data will show the same trends as that presented in Figs 10 and 11. The predicted and measured data are compared on the basis of angle of incidence α rather than lift coefficient C_L, since the C_L measured in the wind-tunnel tests is for the wing alone and hence is not immediately comparable with the trimmed C_L for the complete aircraft in flight.

A number of points may be noted from Figs 10 and 11.

(1) The onset of buffet ($\alpha \sim 9^o$) and the initial penetration response ($\alpha \sim 10^o$) measured in flight agree well with predictions from the tunnel data with forward transition, at both 26^o and 35^o sweep.

(2) At 26^o sweep the response at deeper penetration ($\alpha \sim 11^o$) is predicted more successfully from the tunnel data with rearward transition fix.

(3) The response measured in flight at incidences below buffet onset is probably due to atmospheric turbulence and hence is not strictly comparable with the predictions made from tunnel tests, where the excitation is due to tunnel background noise. It does serve to indicate, however, that the level of background noise in the 8ft × 8ft wind-tunnel at RAE is low enough to enable buffet onset and initial penetration to be defined as accurately as is possible in flight.

(4) At 26^o sweep, the general level of damping is well predicted from the tunnel data, particularly with regard to the damping increase with incidence beyond buffet onset. Also notable is the agreement between damping estimates based on the tunnel data with forward and rearward transition fixes.

(5) At 35^{o} sweep, the predicted damping at low incidence tends to be higher than the flight values, possibly reflecting the scatter in the tunnel measurements at 35^{o} sweep apparent from Figs 7 and 9.

5 CONCLUDING REMARKS

Preliminary results of a flight/tunnel comparison of the levels of buffeting response intensity of the TACT aircraft have been presented. Using a technique which has been under development at RAE, wind-tunnel measurements of the buffeting response of a 1/8-scale half-model of conventional construction have been used to predict the response of the TACT aircraft under full-scale flight conditions at a Mach number of 0.8 and wing sweeps of 26^{o} and 35^{o}. The results indicate that at 26^{o} sweep, the response intensity measured in flight during initial penetration into buffet is in agreement with predictions based on tunnel tests with transition fixed at 5% chord, whereas deeper penetration is in accord with results from tests with transition fixed at 15% chord.

It is planned to extend the analysis of tunnel and flight data to cover the torsional modes. This correlation may be more difficult than that for the first bending mode, however, since mass asymmetry effects[14] give rise to a number of asymmetric torsional modes on the aircraft, compared to the single mode excited on the model.

Table 1

TEST PARAMETERS

Parameter	Full-scale	1/8-scale half-model
Mean chord, $\bar{c}$	10.18 ft	1.272 ft
Wing area, S	603.9 ft^2	4.718 ft^2*
Dynamic pressure, q	300 to 450 lb/ft^2	665 to 1330 lb/ft^2
Reynolds number, R	24 to 32 × 10^6	5.4 to 10.8 × 10^6
Flow velocity, V	800 to 830 ft/s	870 ft/s

Table 2

MODAL PARAMETERS FOR FIRST SYMMETRIC WING BENDING MODE

Parameter	26° sweep		35° sweep	
	Full-scale	1/8-scale half-model	Full-scale	1/8-scale half-model
Natural frequency f_0	4.54 Hz	44.0 Hz	4.58 Hz	44.5 Hz
Frequency parameter $n_0 = \bar{c}\omega_0/V$	0.35 to 0.36	0.40	0.36 to 0.37	0.41
Generalised mass m	2148 lb	8.2 lb*	2190 lb	8.5 lb*
Structural damping ζ_s	1.1% critical	0.2%	1.0%	0.2%

* denotes value for single wing

LIST OF SYMBOLS

$\bar{c}$	mean chord
f	frequency
f_0	undamped natural frequency
m	generalised mass
n_0	non-dimensional natural frequency
q	dynamic pressure
t	time
$z(t)$	generalised coordinate
E	non-dimensional buffet excitation parameter
$G(f)$	power spectral density function
K	non-dimensional aerodynamic damping parameter
S	wing area
V	flow velocity
$X(t)$	generalised aerodynamic excitation
α	angle of incidence
ζ	total damping ratio
ζ_a	aerodynamic damping ratio
ζ_s	structural damping ratio
ρ	air density
σ	rms acceleration
ω	angular frequency
ω_0	undamped angular natural frequency

REFERFNCES

No.	Author	Title, etc
1	J.G. Jones	Modelling of systems with a high level of internal fluctuations. AGARD-CP-172 (1974)
2	G.F. Butler G.R. Spavins	Preliminary evaluation of a technique for predicting buffet loads in flight from wind-tunnel measurements on models of conventional construction. AGARD CP 204 (1976)
3	G.F. Butler G.R. Spavins	The prediction of buffeting response in flight from wind-tunnel tests on models of conventional construction. RAE Technical Report (in preparation)
4	J.G. Jones	A survey of the dynamic analysis of buffeting and related phenomena. RAE Technical Report 72197 (1973)
5	D.G. Mabey G.F. Butler	Measurement of buffeting on two 65° delta wings of different materials. RAE Technical Report 76009 (1976)
6	H.A. Cole Jnr	On-line failure detection and damping measurement of aerospace structures by random decrement signatures. NASA CR 2205 (1973)
7	P.R. Wilcox W.L. Crawford	A least squares method for the reduction of free oscillation data. NASA TN-D 4503 (1968)
8	C.W. Skingle K.H. Heron D.R. Gaukroger	Numerical analysis of plots of vector response loci. RAE Technical Report 73001 (1973)
9	G.F. Butler	MADAM - a computer program for Modal Analysis by Differencing And Minimisation. RAE Technical Report (in preparation)
10	E.R. van Driest C.B. Blumer	Effect of roughness on transition in supersonic flow. AGARD Report 255 (1960)

REFERENCES (concluded)

No.	Author	Title, etc
11	P.W. Hanson	Structural and aerodynamic quantities of the dynamic system, similarity laws and model testing. AGARD AR-82 (1975)
12	L.S. Voelker	Measurement of the natural frequencies and mode shapes of the TACT aircraft. AFFDL-TM-74-42-FYS (1974)
13	-	TACT airplane ground vibration test data. Unpublished AFFDL Report (1973)
14	L.S. Voelker	Mass asymmetry effects on the vibration characteristics of the TACT aircraft. AFFDL-TM-74-41-FYS (1974)

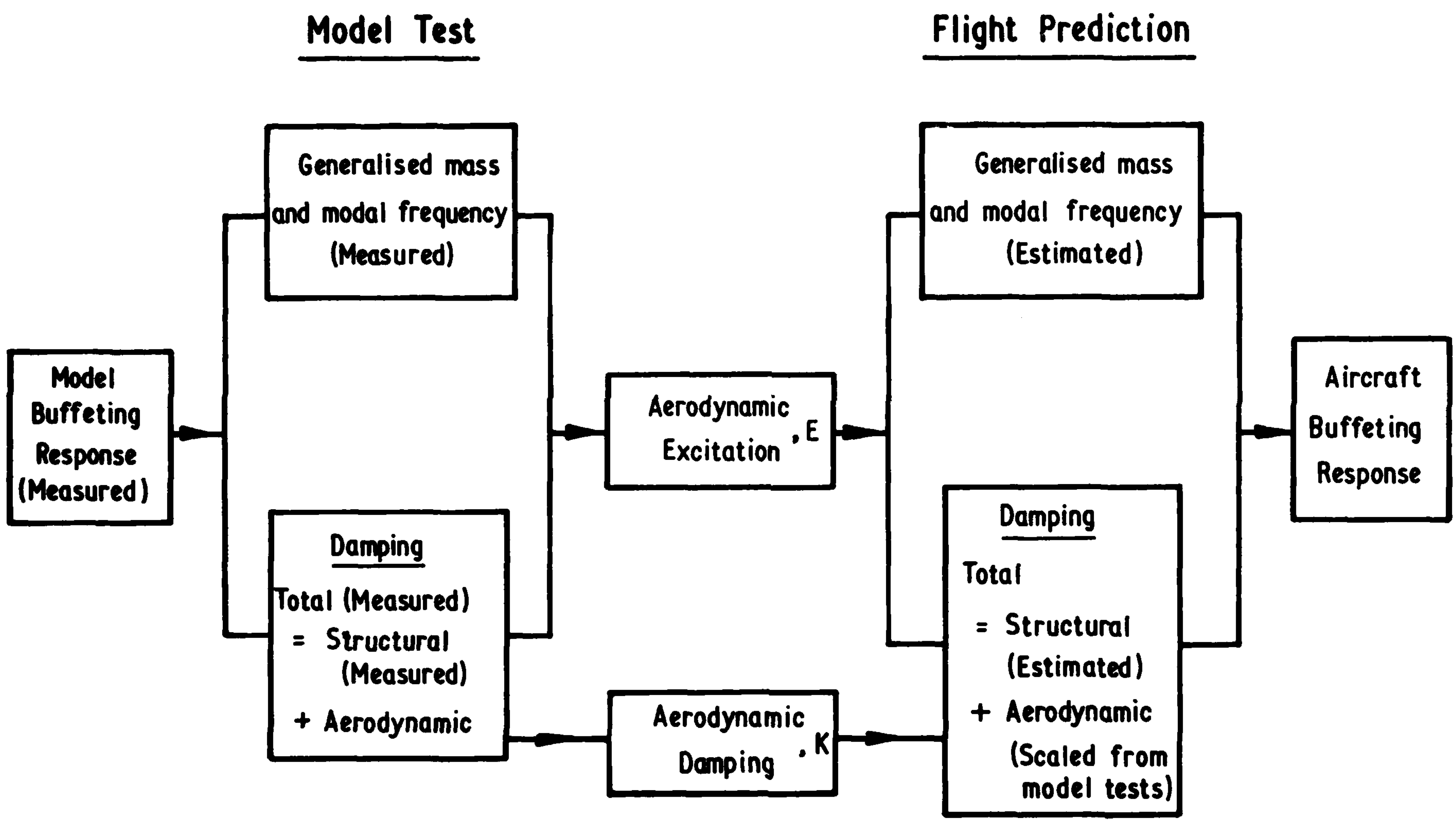
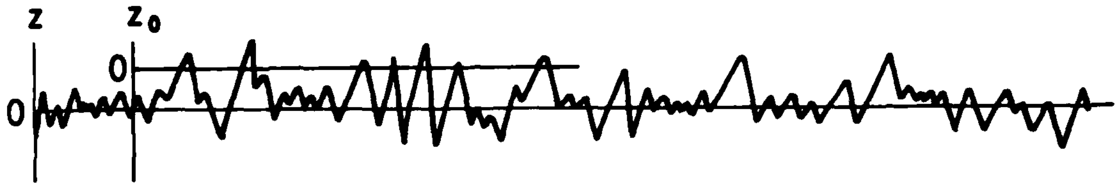


Fig. 1 Buffeting Prediction Method

Fig. 2

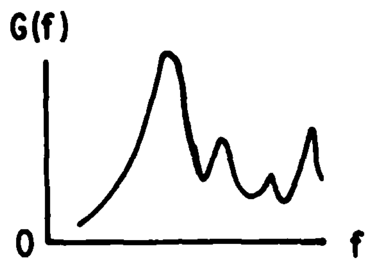
Typical Random Response



<u>Spectral Density</u>

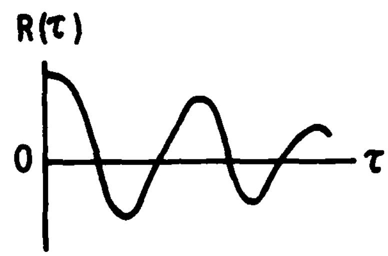
$$G(f) = \frac{1}{N}\sum_{n=1}^{N}\frac{2}{T}\left|\int_0^T z(t)\,e^{-i2\pi ft}\,dt\right|^2$$

$$\lim N \to \infty$$



<u>Autocorrelation</u>

$$R(\tau) = \lim_{T\to\infty}\frac{1}{T}\int_0^T z(t)\,z(t+\tau)\,dt$$



<u>Randomdec</u>

$$z_0 = z - z_s$$

$$\delta(\tau) = \frac{1}{N}\sum_{n=1}^{N} z_0(t_n + \tau)$$

$$\lim N \to \infty$$

with $t_n = t$ when $z_0 = 0$

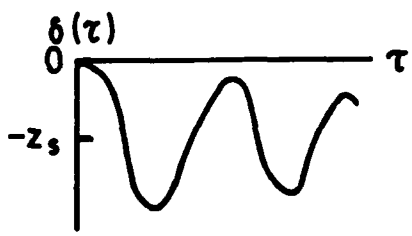


Fig. 2 Characteristic functions obtained from a random response

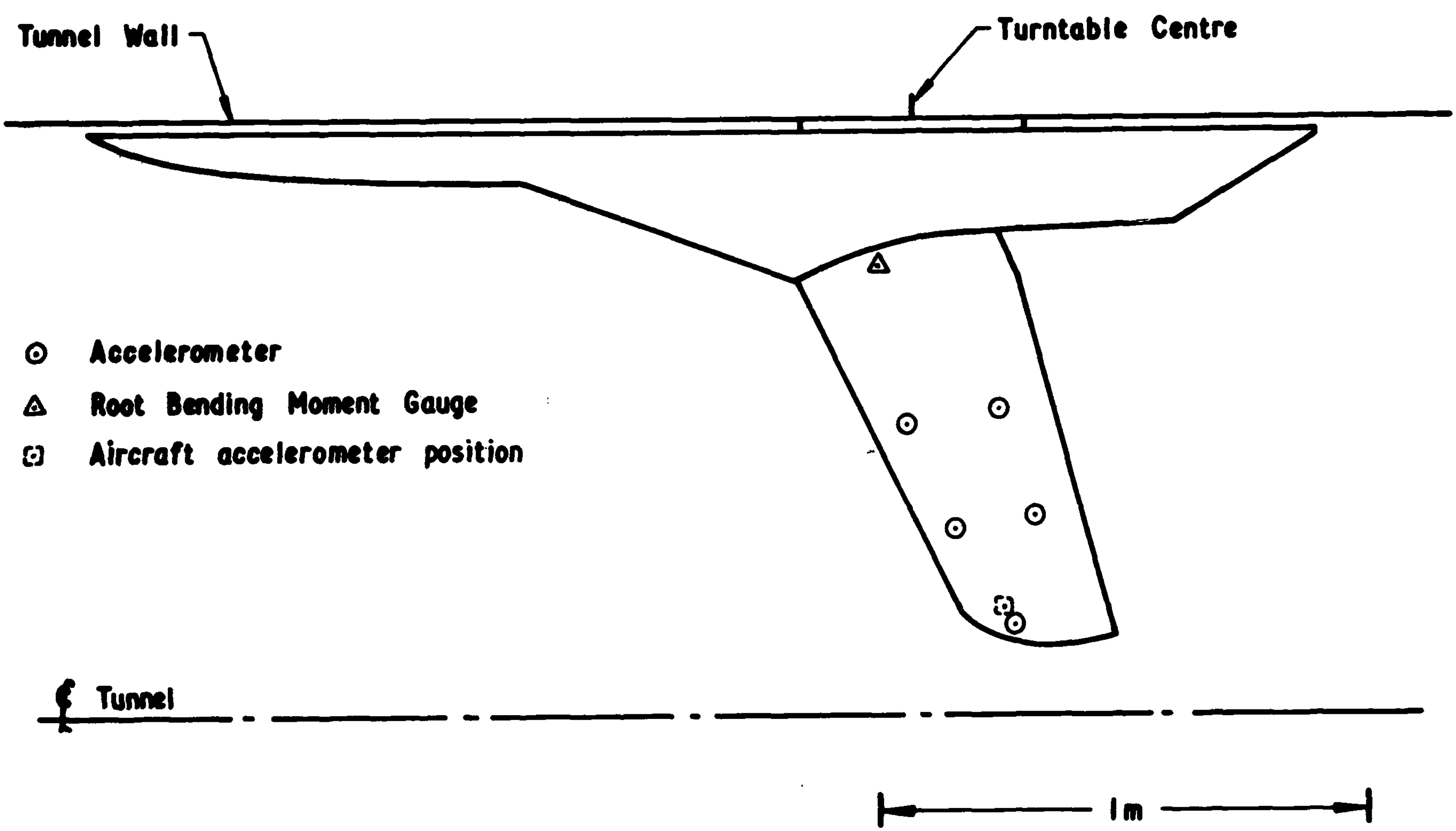


Fig. 3 Half-model of TACT F111 in RAE 8' x 8' Wind Tunnel

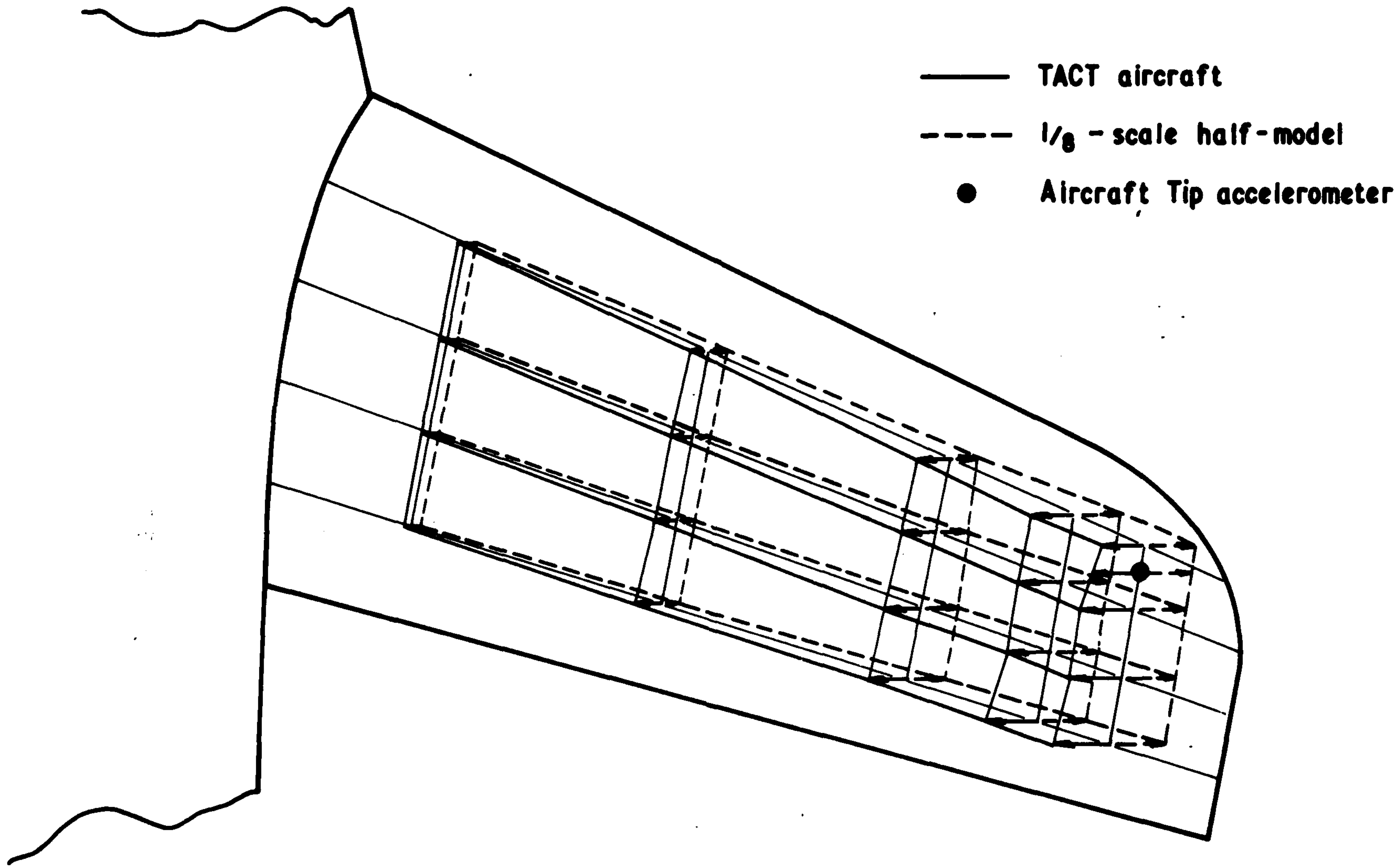


Fig. 4 Comparison of 1st Wing Symmetric Mode-shape for $1/8$-scale half-model and TACT aircraft

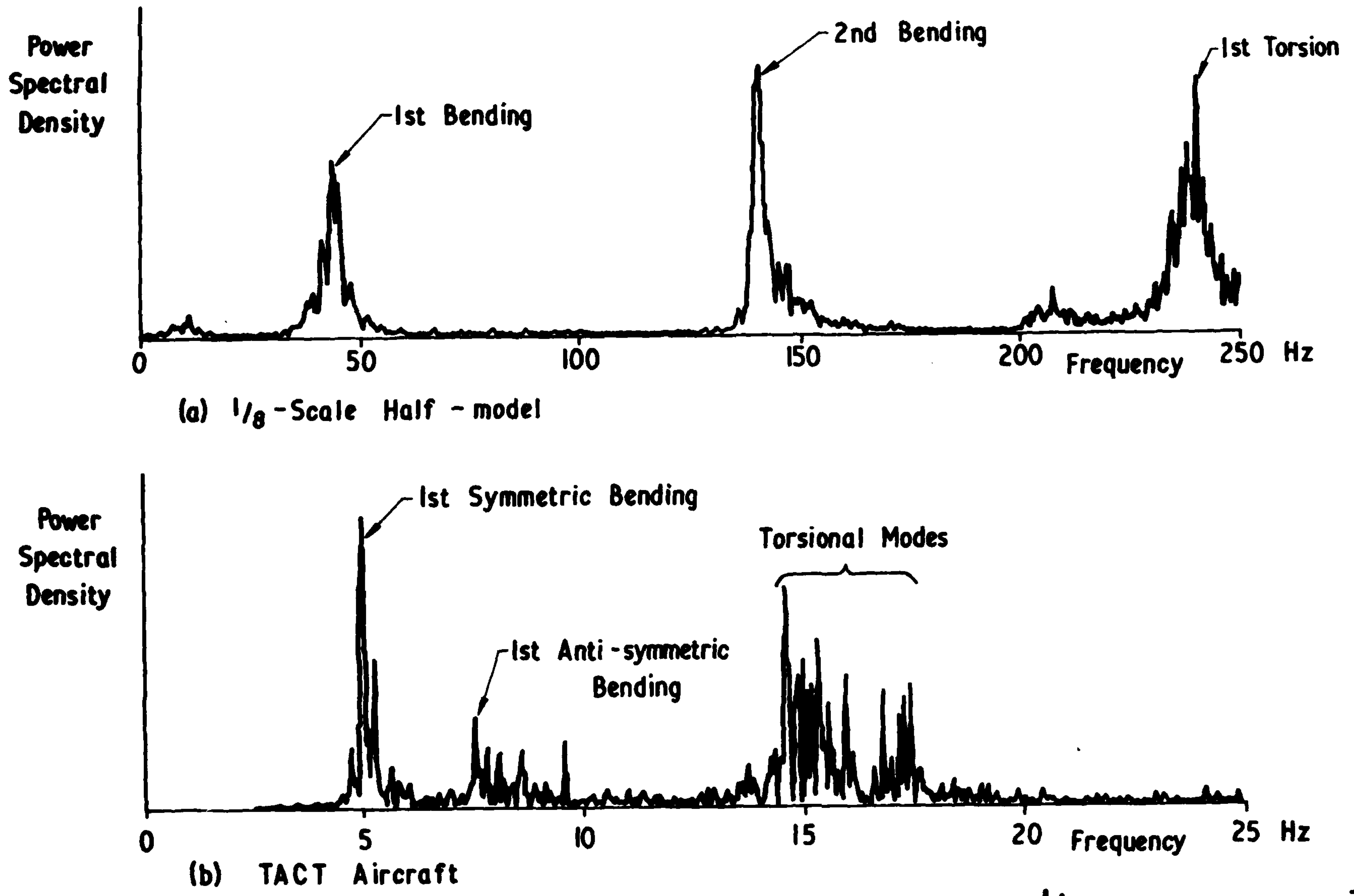


Fig 5 Comparison of response at wingtip accelerometer between 1/8-scale half-model and TACT aircraft.

Fig. 6

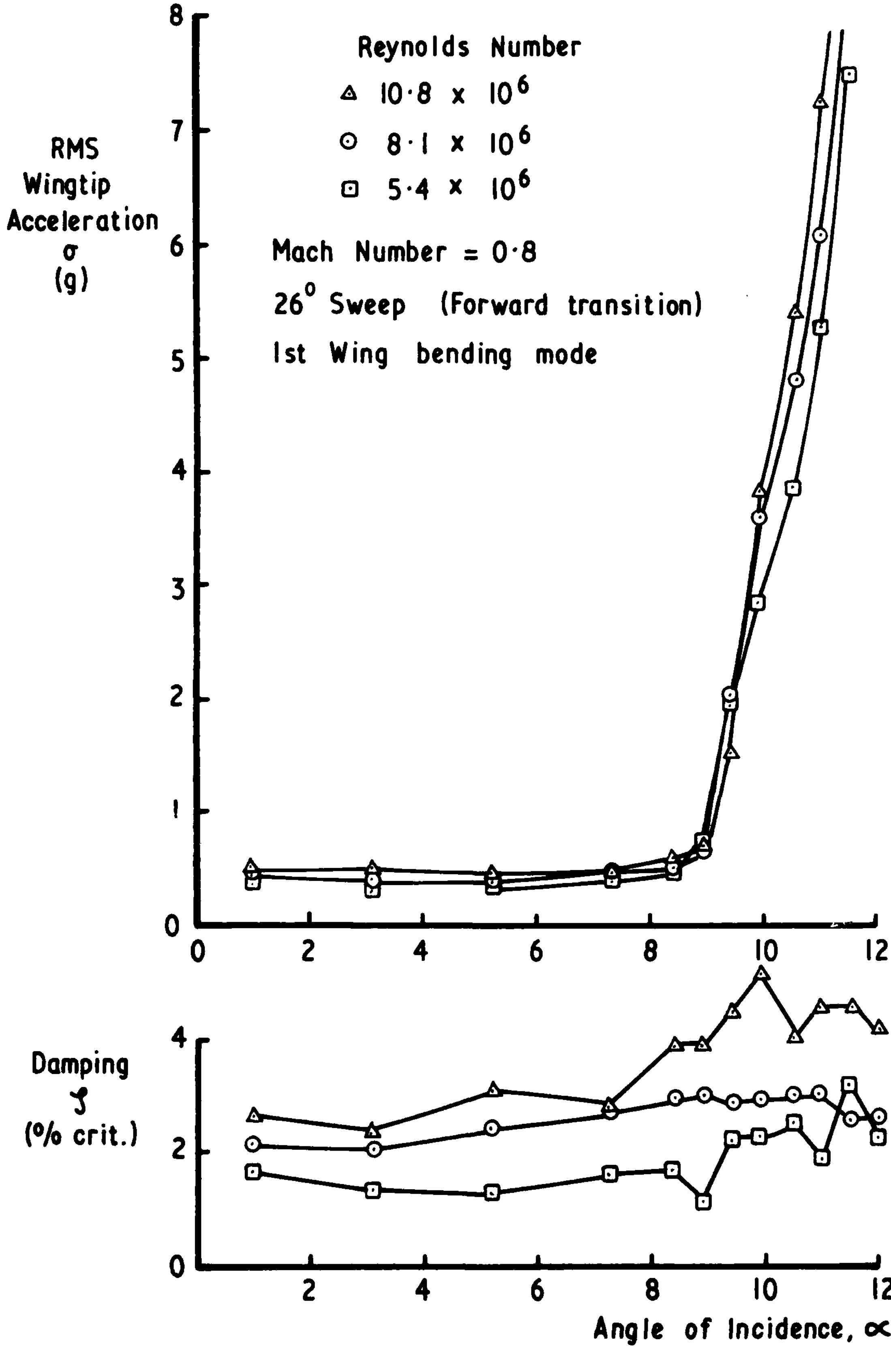


Fig. 6 Tunnel measurements of rms wingtip acceleration, σ and damping ζ v angle of incidence, α. 26° Sweep

T. Memo Aero 1806

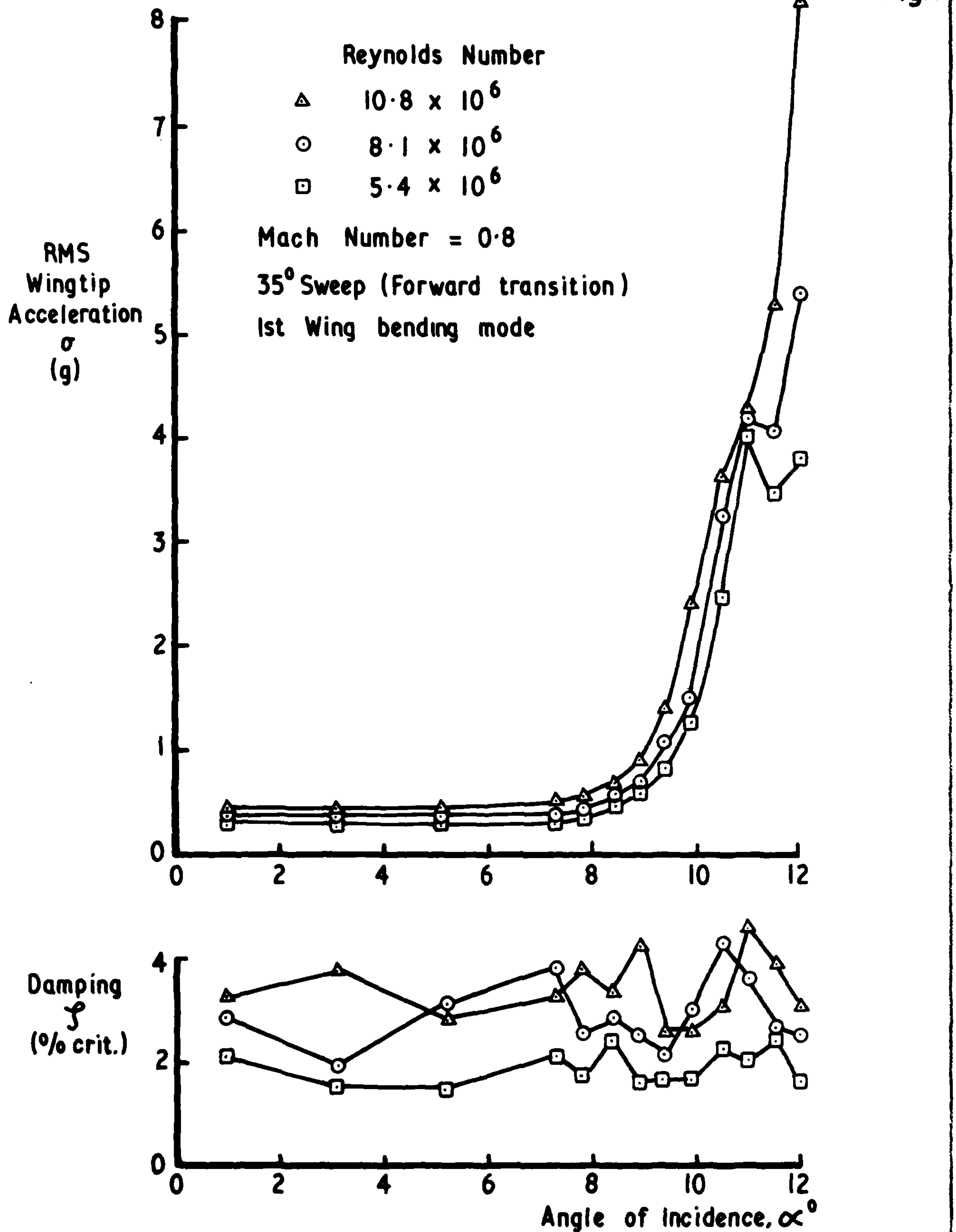


Fig. 7 Tunnel measurements of rms wingtip acceleration, σ and damping, ζ v angle of incidence, α. 35° Sweep

Fig.8

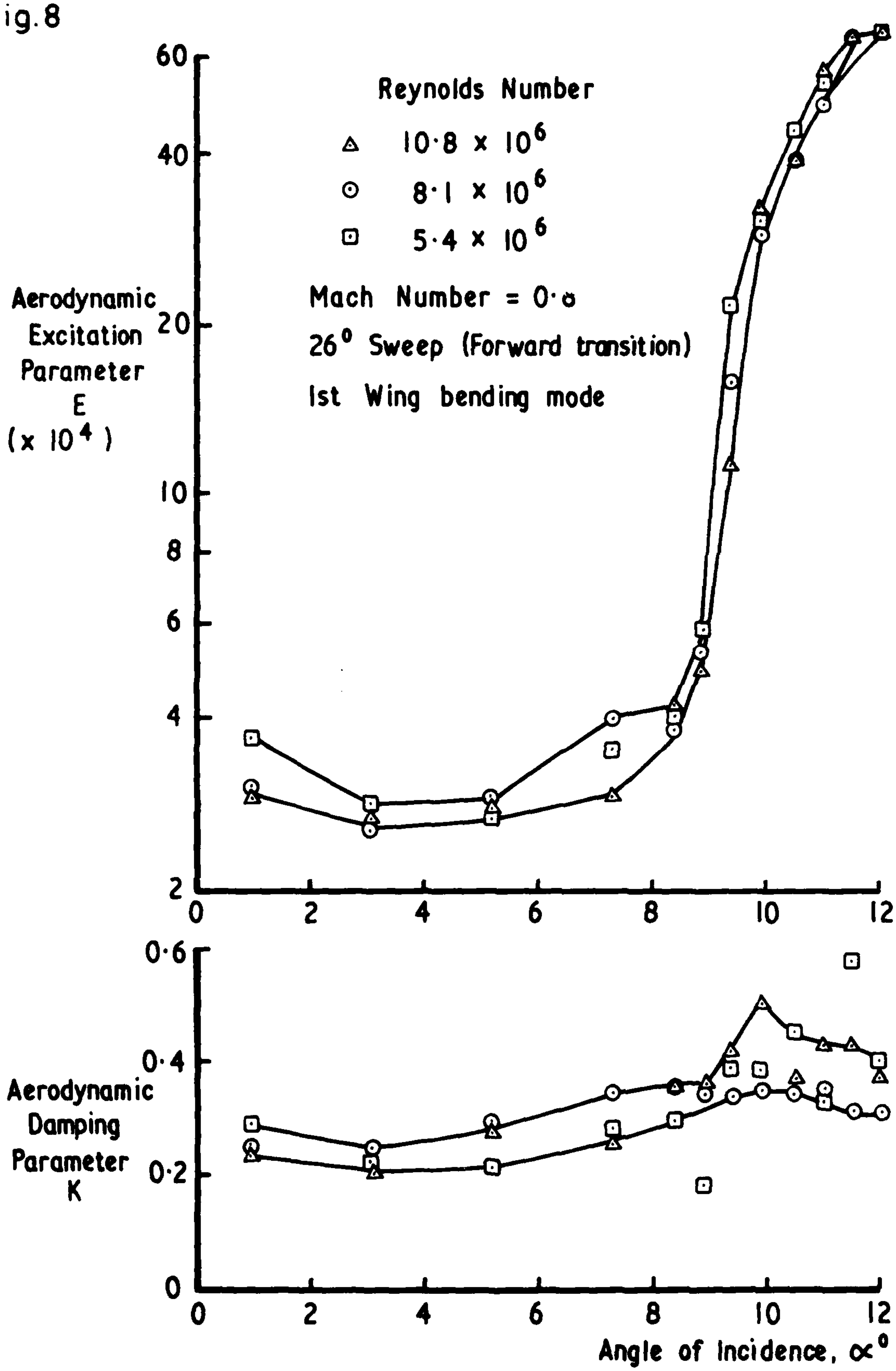


Fig. 8 Excitation parameter, E and aerodynamic damping parameter K v angle of incidence, α . 26° Sweep

T. Memo Aero 1806

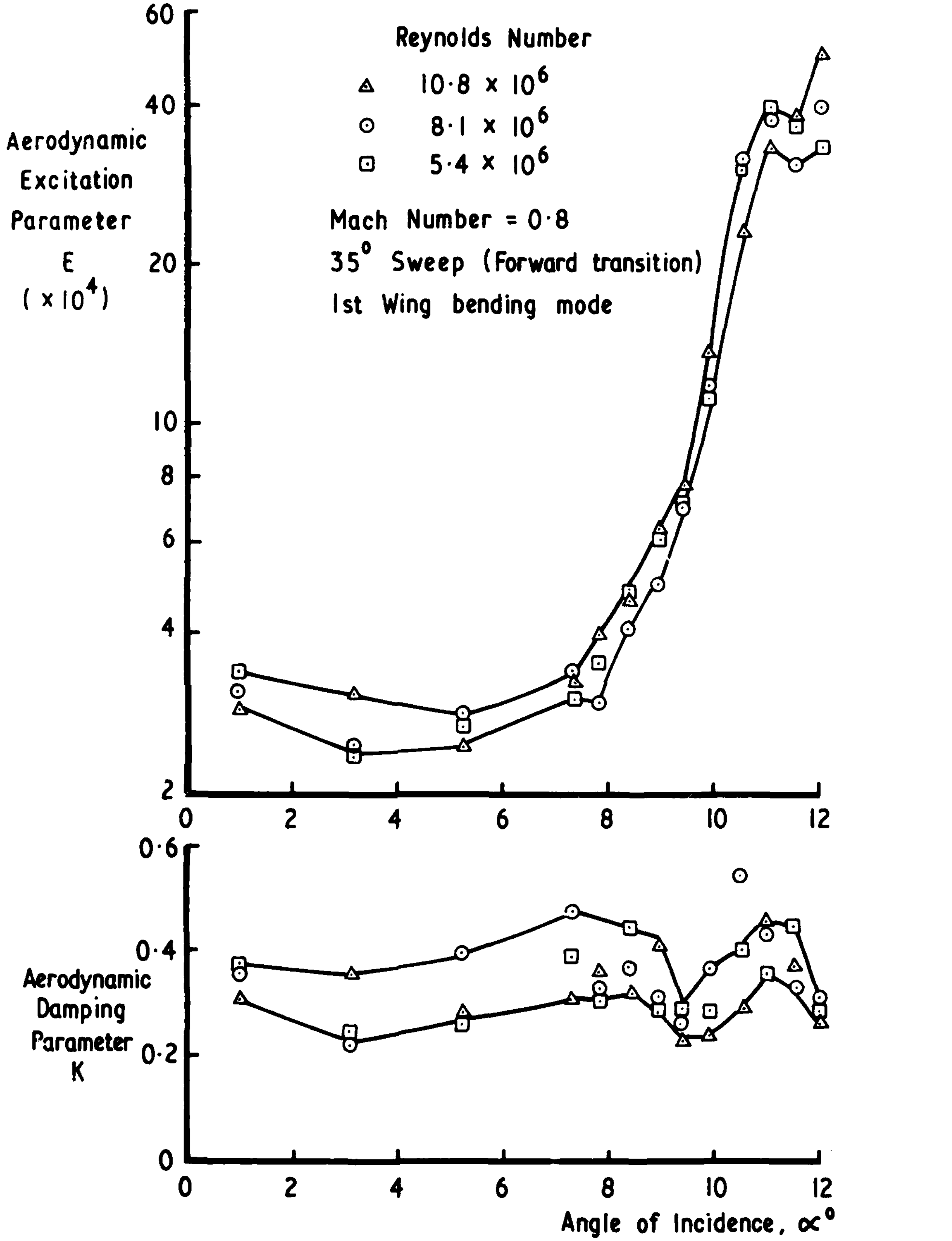


Fig. 9 Excitation parameter, E and aerodynamic damping parameter K v angle of incidence, α . 35^0 Sweep

Fig.10

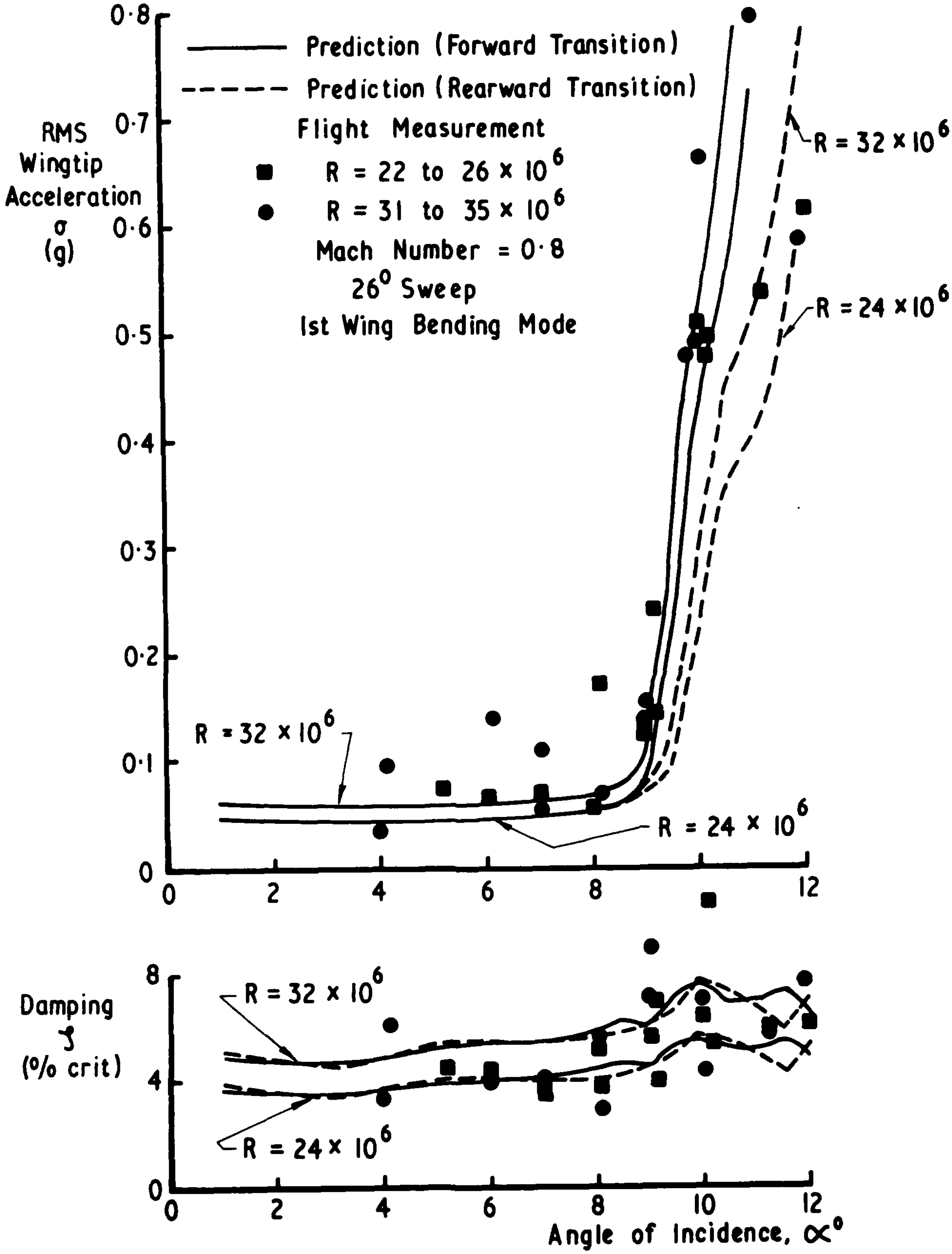


Fig. 10 Predicted and measured RMS wingtip acceleration, σ and damping, ζ v angle of incidence, α (26° Sweep)

T. Memo Aero 1806

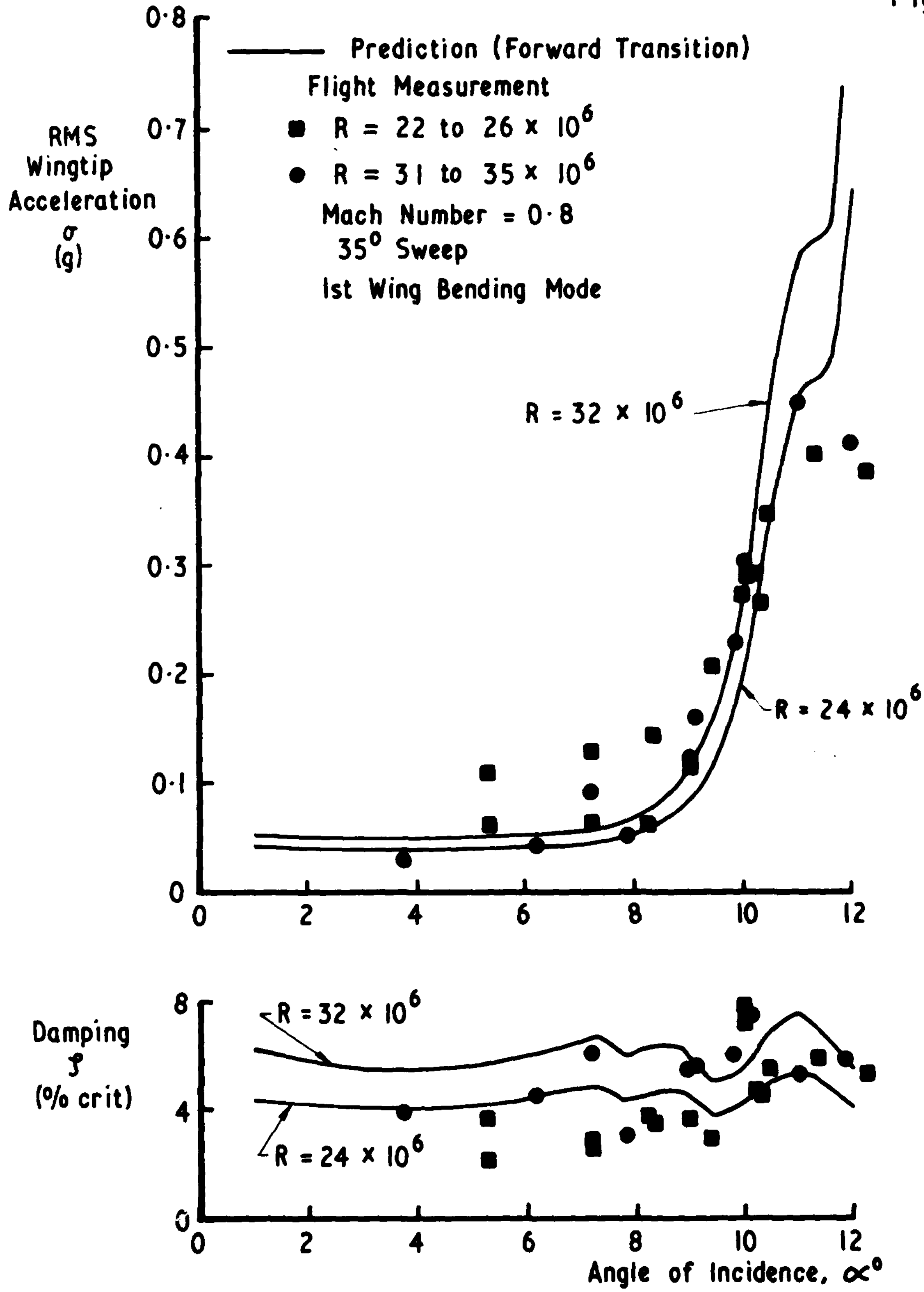


Fig. 11 Predicted and measured RMS wingtip acceleration, σ and damping, ζ v angle of incidence, α (35° Sweep)

REPORT DOCUMENTATION PAGE

Overall security classification of this page

UNLIMITED

As far as possible this page should contain only unclassified information. If it is necessary to enter classified information, the box above must be marked to indicate the classification, e.g. Restricted, Confidential or Secret.

1. DRIC Reference (to be added by DRIC)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification/Marking
	RAE TM Aero 1806	N/A	UNLIMITED

5. DRIC Code for Originator	6. Originator (Corporate Author) Name and Location
7673000W	Royal Aircraft Establishment, Farnborough, Hants, UK
5a. Sponsoring Agency's Code	**6a. Sponsoring Agency (Contract Authority) Name and Location**
N/A	N/A

7. Title Wind-tunnel/flight comparison of the levels of buffeting response intensity for the TACT F-111

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

USAF/NASA Symposium on Transonic Aircraft Technology, Lancaster, California, August 1978

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Butler, G.F.	Spavins, G.R.		May 1979	27	14

11. Contract Number	12. Period	13. Project	14. Other Reference Nos.
N/A	N/A		

15. Distribution statement

(a) Controlled by – Head of Aerodynamics Department

(b) Special limitations (if any) –

16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Aerodynamics. Wings. Buffeting.

17. Abstract

Under a UK/US collaboration programme, a wind-tunnel/flight correlation has been made of the levels of buffeting response intensity of the TACT F-111 aircraft. Using a technique which has been under development at RAE, wind-tunnel measurements of the buffeting response of a 1/8-scale half-model of conventional construction have been used to predict the response of the TACT aircraft under full-scale flight conditions. Comparison with flight measurements shows good agreement.